## ESE National Applications:

*Atmospheric Measurements and Predictions for Air Quality Management*

**Center Program Manager Review**

*Oct. 28, 2002*

*Accelerating the realization of economic and societal benefits from Earth science, information, and technology …*

## Overview

Air Quality Application:

Evaluate and benchmark NASA datasets and assimilation techniques for use in air quality models to support operational air quality planning, attainment evaluations, and emissions control strategies.

Primary Federal Partners: EPA & NOAA

Overall Themes:

A. Compare NASA measurements with EPA ground networks

B. Evaluate NASA products within EPA CMAQ model

C. Examine Near Real Time data product support

D. Investigate needs & support to future Air Quality forecasting

## Overview

Air Quality Application:

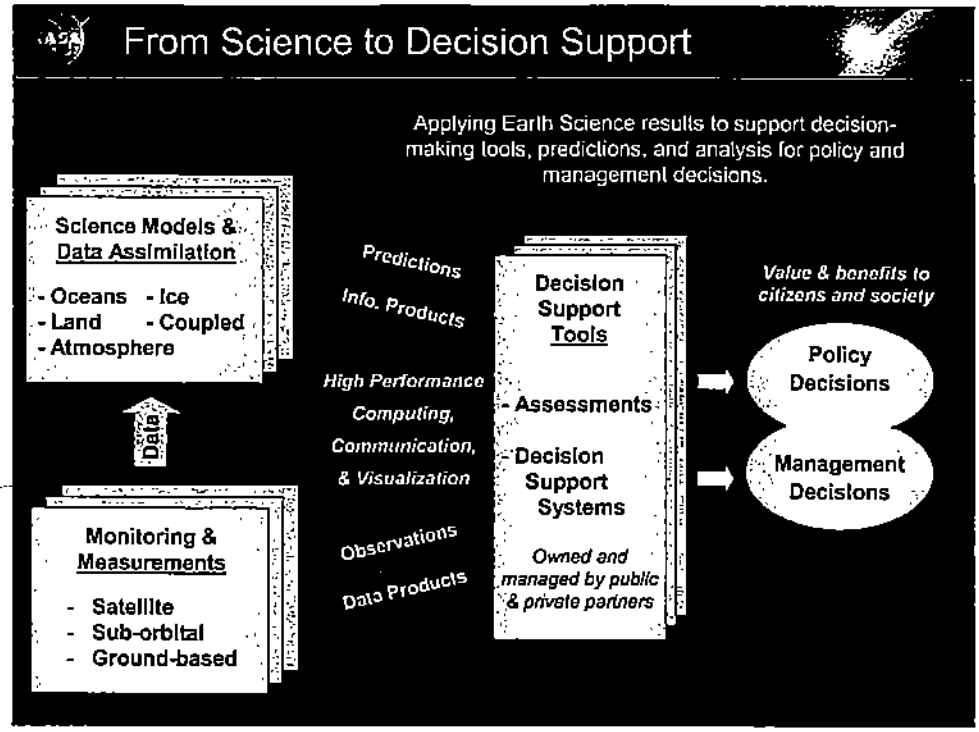
Evaluate and benchmark NASA datasets and assimilation techniques for use in air quality models to support operational air quality planning, attainment evaluations, and emissions control strategies.

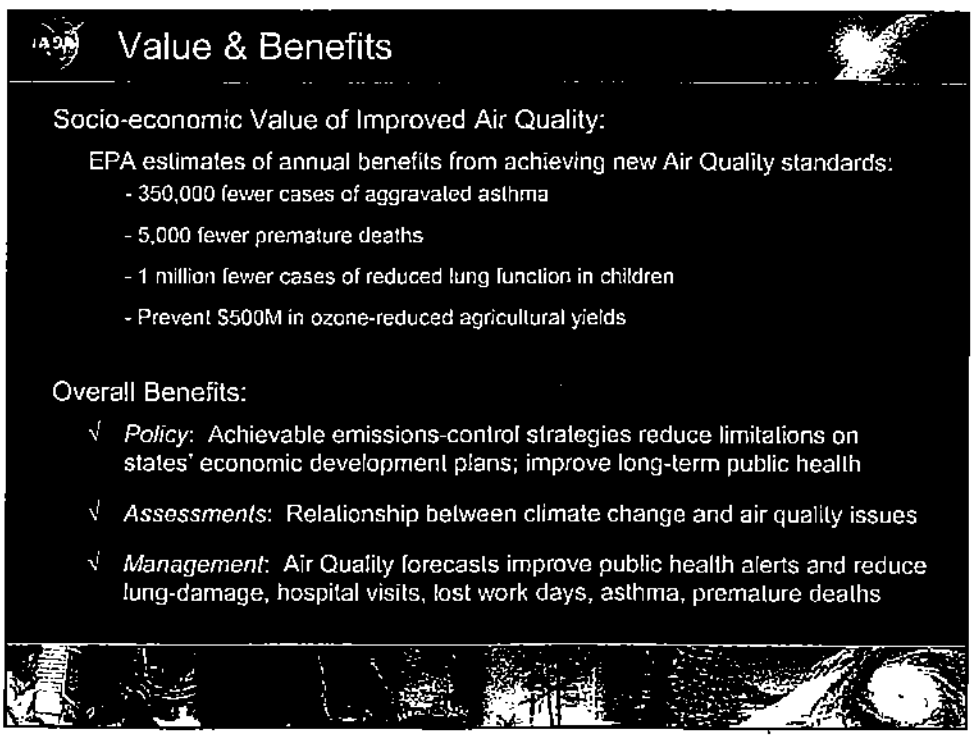
Air Quality Applications Team, including:

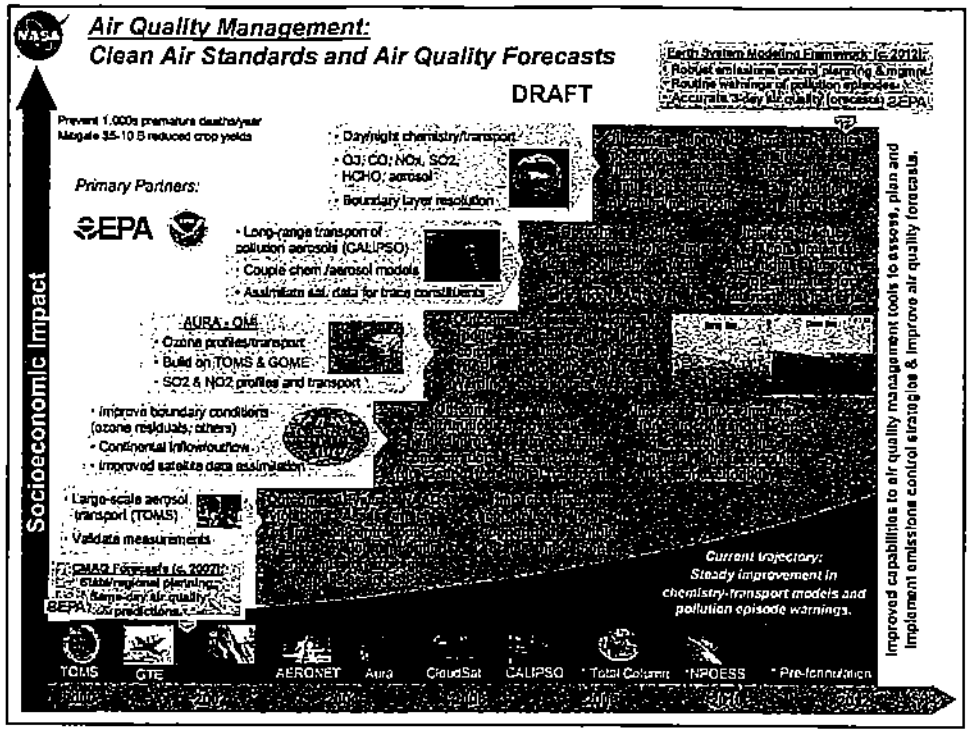
| | | |
|---|---|---|
| Doreen Neil/LaRC | Jim Szykman/EPA (LaRC) | Jack Fishman/LaRC |
| Brad Pierce/LaRC | Nathan Sovik/SSC | Lawrence Friedl/HQ |
| Jim Gleason/HQ | Phil DeCola/HQ | Don Johnson/UW-Mad. |
| Others TBD | | |

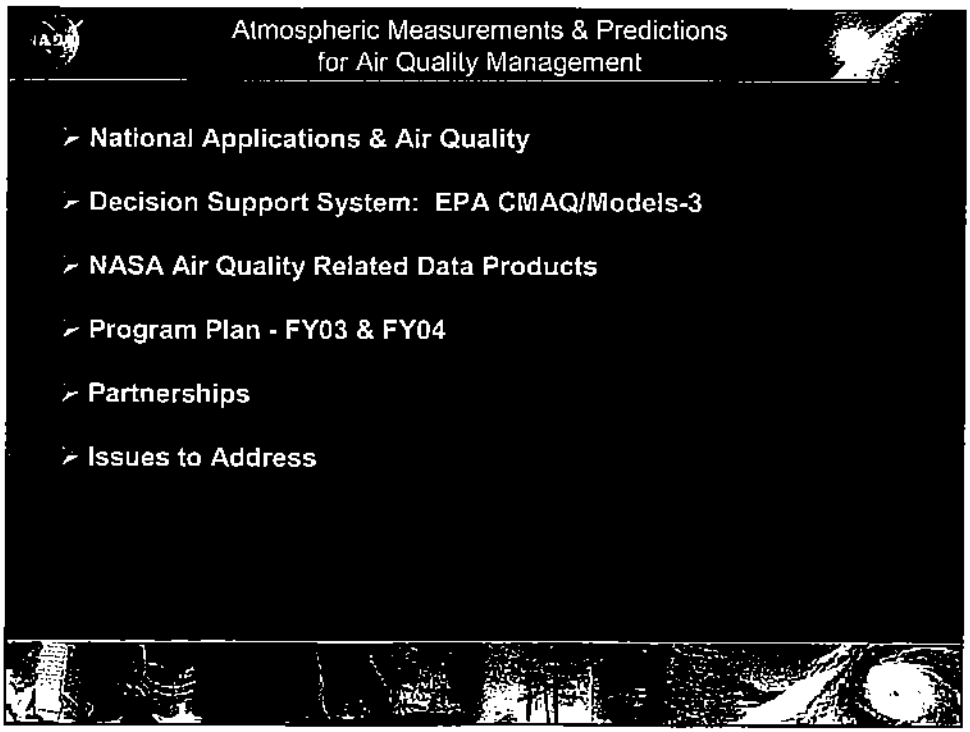
## Atmospheric Measurements & Predictions for Air Quality Management

- National Applications & Air Quality
- Decision Support System: EPA CMAQ/Models-3
- NASA Air Quality Related Data Products
- Program Plan - FY03 & FY04
- Partnerships
- Issues to Address


From Science to Decision Support
Applying Earth Science results to support decision-making tools, predictions, and analysis for policy and management decisions.
Science Models & Data Assimilation
- Oceans - Ice
- Land - Coupled
- Atmosphere
Data
Monitoring & Measurements
- Satellite
- Sub-orbital
- Ground-based
Predictions
Info. Products
High Performance Computing, Communication, & Visualization
Observations
Data Products
Decision Support Tools
- Assessments
- Decision Support Systems
Owned and managed by public & private partners
Value & benefits to citizens and society
Policy Decisions
Management Decisions


Value & Benefits
Socio-economic Value of Improved Air Quality:
EPA estimates of annual benefits from achieving new Air Quality standards:
- 350,000 fewer cases of aggravated asthma
- 5,000 fewer premature deaths
- 1 million fewer cases of reduced lung function in children
- Prevent $500M in ozone-reduced agricultural yields
Overall Benefits:
√ Policy: Achievable emissions-control strategies reduce limitations on states' economic development plans; improve long-term public health
√ Assessments: Relationship between climate change and air quality issues
√ Management: Air Quality forecasts improve public health alerts and reduce lung-damage, hospital visits, lost work days, asthma, premature deaths


Air Quality Management:
Clean Air Standards and Air Quality Forecasts
DRAFT
Earth System Modeling Framework (c.2012):
Prevent 1,000s premature deaths/year
Mitigate $5-10 B reduced crop yields
Primary Partners:
EPA
• Daylight chemistry/transport
• O3; CO; NOx; SO2; HCHO; aerosol
• Boundary layer resolution
• Long-range transport of pollution aerosols (CALIPSO)
• Couple chem./aerosol models
• Assimilate sat. data for trace constituents
AURA - OMI
• Ozone profiles/transport
• Build on TOMS & GOME
• SO2 & NO2 profiles and transport
• Improve boundary conditions (ozone residuals, others)
• Continental inflow/outflow
• Improved satellite data assimilation
• Large-scale aerosol transport (TOMS)
• Validate measurements
CMAQ Forecasts (c. 2007):
• State/regional planning
• Real-time air quality predictions
Socioeconomic Impact
Current trajectory:
Steady improvement in chemistry-transport models and pollution episode warnings.
Improved capabilities to air quality management tools to assess, plan and implement emissions control strategies & improve air quality forecasts.
TOMS
GTE
AERONET
Aura
CloudSat
CALIPSO
Total Column
NPOESS
Pre-formulation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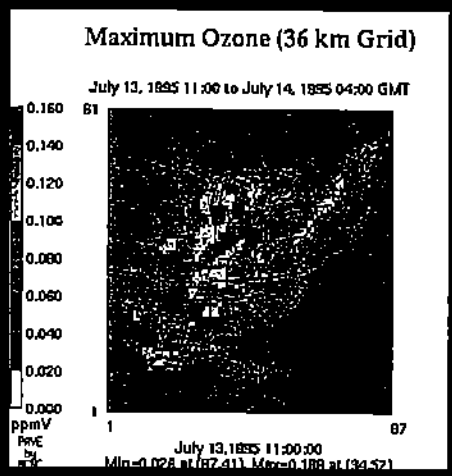
## US National Air Quality Policy

**US Environmental Protection Agency (EPA)**

- EPA sets health-based standards for multiple pollutants
- Ground network determines areas that violate standards
- Areas develop plans to meet the standards
  - Develop pollution control strategies
  - Use models to evaluate scenarios and make decisions
- Economic restrictions if fail to meet plan and standards

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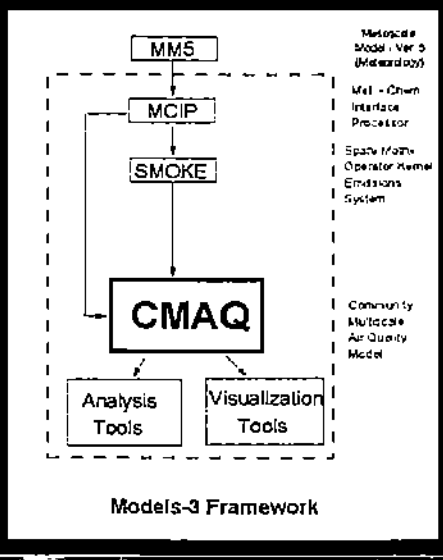
**Role of Space-based Measurements in Air Quality Policy**

- Coverage over vast areas & can fill-in gaps between ground monitors
- Assess global and regional transport
- Improve inventory of emissions sources for air quality models
- Provide boundary conditions for air quality models

## Air Quality DSS: EPA CMAQ/Models-3

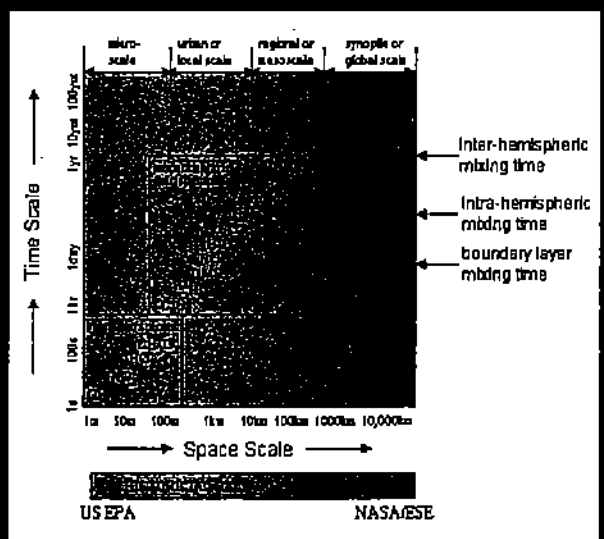



- Meteorology
- Pollution & Emissions
- Atmospheric Chemistry

"Criteria" pollutants:

$NO_2$, $SO_2$, Pb, $O_3$ (VOC), CO, $PM_{10}$, $PM_{2.5}$

## Space in Operational & Research Agencies




Intended application drives the focus of different agencies over spatial and temporal scales of atmospheric constituents.

*Adapted from: National Academy of Sciences, 1998*

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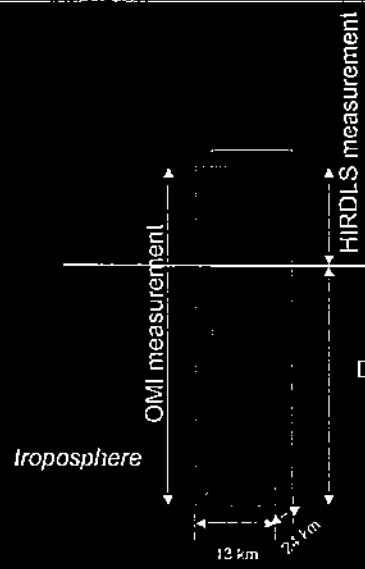
## NASA Air Quality Data Products

Data Products:

- Tropospheric Residuals
- Assimilated Data

## Total Column and Tropospheric Residual

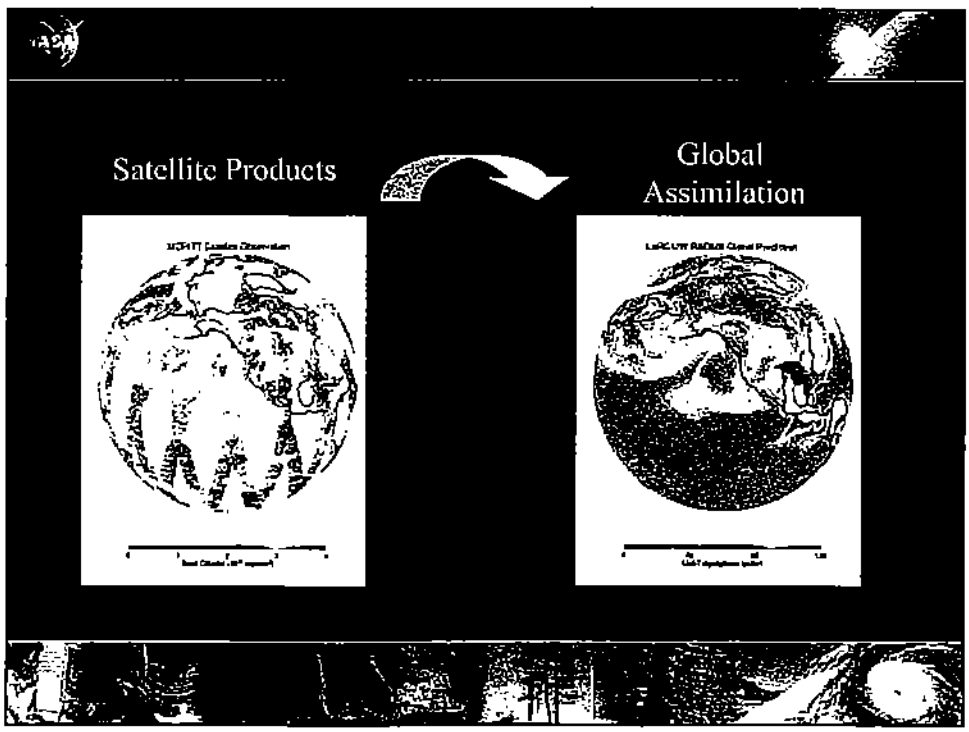



In general, tropospheric column density is determined using coincident measurements

Difference = "tropospheric residual"

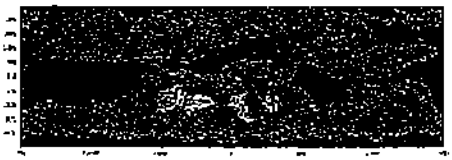
Note: OMI horizontal resolution varies from 13 km x 24 km at nadir to about ~100 km at the extreme off-nadir.

Source: Fishman, J., Chandra, S., Ziemke, J., *Draft OMI-ATBD, Chapter 5: Tropospheric $O_3$ Residual*, May 2002

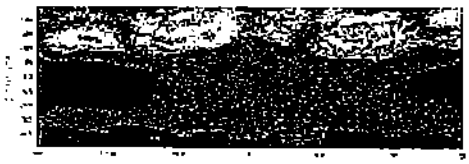


## 2000 Seasonal Tropospheric Ozone Residual (TOR)
## (Dec 99 – Nov 00)

TROPOSPHERIC OZONE RESIDUAL (TOR) DJF 2000

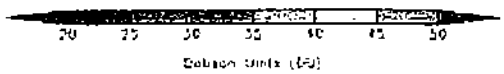


TROPOSPHERIC OZONE RESIDUAL (TOR) MAM 2000



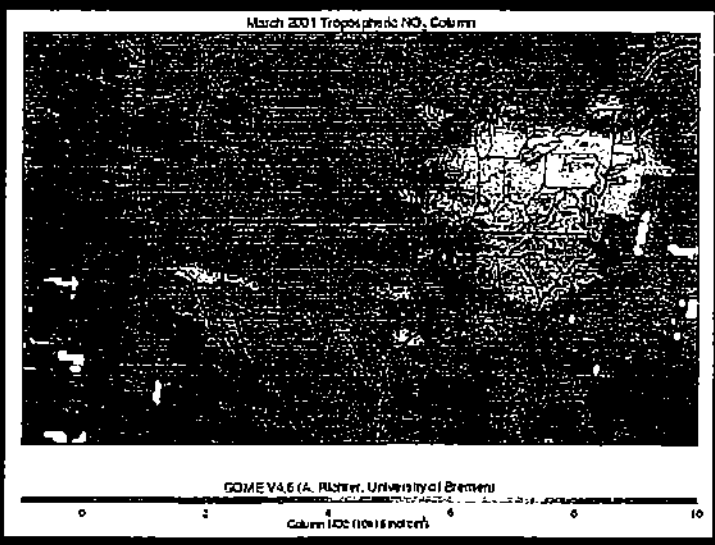
TROPOSPHERIC OZONE RESIDUAL (TOR) JJA 2000

TROPOSPHERIC OZONE RESIDUAL (TOR) SON 2000

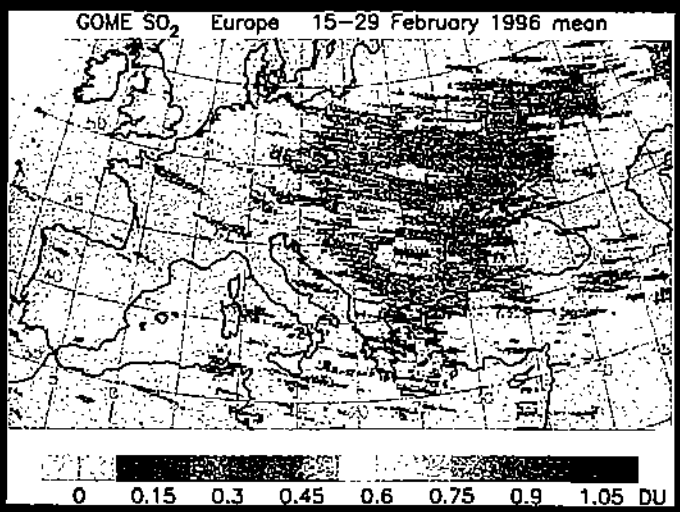



Source: (Fishman and Balok, NASA/LaRC)

## $NO_2$ Measurements from GOME



## Initial $SO_2$ Measurements from GOME




Anthropogenic Emissions over Europe

Source: A. Richter, University of Bremen

## AURA-OMI Tropospheric Residual Data Products

$O_3$

$NO_2$

$SO_2$

HCHO

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## AQ Program Goals & Activities

A. Compare NASA data products with EPA ground network measurements

B. Evaluate NASA assimilated products and boundary conditions within EPA CMAQ model

C. Examine Near Real Time data product support (AURA-OMI)

D. Support to future Air Quality forecasting activities

## AQ Program Goals & Activities

**A. Compare NASA data products with EPA ground network measurements**

*- Do NASA products improve on ground monitors, fill-in gaps on ground, and improve CMAQ runs?*

**B. Evaluate NASA assimilated products and boundary conditions within EPA CMAQ model**

*- How well do RAQMS products match ground monitors?*

*- Does CMAQ need to account for above-ground?*

**C. Examine Near Real Time data product support (AURA)**

*- What are requirements for CMAQ?*

*- What algorithms, science, or computing might be needed?*

**D. Support to future Air Quality forecasting activities**

*- What decision support forecasting systems will be used?*

## Goal A: Compare NASA data products with EPA ground network measurements

*Evaluate datasets with EPA ground network & value in CMAQ model runs*

FY03

Tropospheric ozone residual (TOMS $0_3$)

GOME column $NO_2$

MOPITT CO

FY04

GOME $SO_2$

MODIS Aerosol Column Depth

HCHO tropospheric column

Products

Evaluation Reports

EPA/NASA Evaluation & Benchmark Conference

## Goal B: Evaluate benefit of NASA-assimilated boundary conditions in EPA CMAQ model

*Benchmark CMAQ with Boundary Condilions to evaluate benefit*
*Evaluate fidelity of RAQMS*

FY03
Assimilated Ozone

FY04
Add Assimilation of GOME column $NO_2$ & MOPITT CO to Assimilated Ozone

Products
Evaluation Reports
EPA/NASA Evaluation & Benchmark Conference

## Goal C: Examine Near Real Time data product support (AU

*Determine CMAQ data handling requirements*
*Discuss opportunities and identify preparations for AURA products*

FY03
Utilize and test with GOME products

FY04
Preparations for OMI & HRDLS
Prototype operational system

Products
If NRT support possible, data product support plan for AURA-OMI & HRDLS

## Goal D: Support to future Air Quality forecasting activities

*Discuss NOAA/EPA activities related to Air Quality forecasts*

FY03
Initiate discussions

FY04
TBD based on activities and FY03 progress
Possible: Test on GOME products, Preparation for AURA products

Products
NASA/NOAA/EPA workshop on Air Quality Forecasting (possible)
If appropriate, Roadmap on ESE Applications support to Air Quality Forecasting

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## Partnerships

NASA Centers:

- Primary: Langley (J. Fishman, D. Neil, B. Pierce, others)
- In work: GSFC (A. Thompson)
  MSFC (RAQMS work)
  SSC (N. Sovik)

Federal Agencies: EPA & NOAA

EPA: J. Szykman (EPA) located at NASA-LaRC

NOAA: Applications relationship in development
*(EPA/NOAA partnership exists for air quality modeling)*

Others

Regional Planning Organizations
Earth modeling centers

## Atmospheric Measurements & Predictions for Air Quality Management

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- **Program Plan - FY03 & FY04**
- **Partnerships**
- **Issues to Address**

## Issues to Address

Air Quality Application:

Evaluate and benchmark NASA datasets and assimilation techniques for use in air quality models to support operational air quality planning, attainment evaluations, and emissions control strategies.

Issues:

- √ Coordination between YO/YS/YF
  - Coordinate funding and support for data products, models
  - Preparation for this meeting identified opportunities
- √ Build relationships with Centers and improve coordination
- √ Near Real Time data products with AURA
  - NRT products and current suite of OMI products
  - System preparations if NRT AURA data products
  - Relationship with Dutch on OMI products
- √ Partners' data quality objectives; standard procedures for data QA/QC

## Back-up Slides

## FY03 Resources

| **FY03 YO Resources:** | Request | Doable |
|---|---|---|
| Tropospheric columns and EPA ground network comparisons | $340 K | $265 K |
| Definition of Near Real Time Data/Assimilated Data Delivery: | $280 K | $235 K |
| *Total* | *$620 K* | *$500 K* |

LaRC RAQMS development and assimilation cost shared

- YS Request $217 K - NASA LaRC $197 K

EPA Partner Resources $200 K

*(Mission definition studies, analysis of pollution episodes, exploratory studies of satellite data)*

## FY04 Resources

FY04 YO Resources: $970K

Tropospheric columns (SO2, aerosol, HCHO) and EPA ground network comparisons ($325K)

RAQMS development and assimilation cost ($190K)

Development of Near Real Time Data/Assimilated Data Delivery: ($355K, TBR)

EPA Partner Resources: requested $500K in FY04

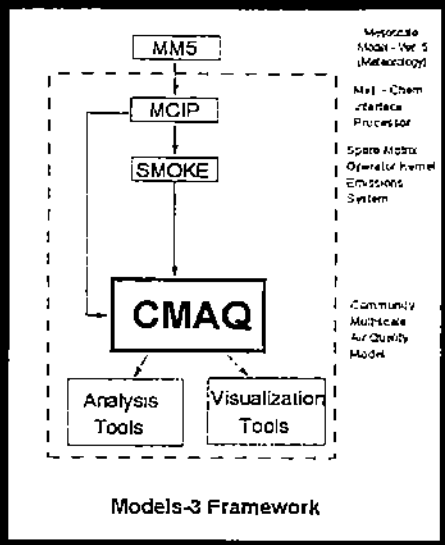
Additional Projects: ~$250K TBR

- Identify prototype aerosol satellite data for comparison to EPA ground networks
- Evaluate aerosol vertical distribution measurements and CMAQ aerosol vert. distrib.

| Instrument | Name | Resolution | AQ Parameter | platform |
|---|---|---|---|---|
| Current and past instruments for tropospheric studies | | | | |
| SCIAMACHY | Scanning Imaging Absorption Spectrometer for Atmospheric ChartographY | Daily<br>~100 km | $O_3$, $NO_x$, $H_2O$, BrO, OCLO, $SO_2$, HCHO, clouds and aerosols | ESA's ENVISAT-1 (2001) |
| GOME | Global Ozone Monitoring Experiment | Weekly<br>~100 km | $O_3$, $NO_x$, $H_2O$, BrO, OCLO, $SO_2$, HCHO, clouds and aerosols | ESA-ERS2 (1995---) |
| MODIS | Moderate Resolution Imaging Spectroradiometer | Daily<br>10 km | Aerosol optical thickness, aerosol type (sulfate, biomass burning) over land | NASA Aqua (2002)<br>Terra (1999) |
| MISR | Multi-angle Imaging SpectroRadiometer | Weekly<br>17.6 km | Aerosol properties (angular radiance dependence) | NASA Terra (1999) |
| MOPITT | Measurement of Pollution in the Troposphere | Weekly<br>~100 km | Total column of CO, $CH_4$ + CO profiles | NASA Terra (1999) |
| SBUV | Solar Backscatter Ultra-violet Ozone Experiment | Daily<br>~100 km | $O_3$ | Nimbus-7 (1979-90) |
| SBUV-2 | Solar Backscatter Ultraviolet Ozone Experiment 2 | Daily<br>~100km | $O_3$ | NOAA-9 (1985-present)<br>NOAA-11 (1989-95)<br>NOAA-14(1995---) |
| TOMS | Total Ozone Monitoring Spectrometer | Daily<br>~100 km | $O_3$<br>aerosol optical depth | Nimbus 7 (1979-92)<br>Meteor (1992-94)<br>ADEOS (1996-97)<br>Earth Probe (1996--) |

| Instrument | Name | Resolution | AQ Parameter | platform |
|---|---|---|---|---|
| Future instruments for tropospheric studies scheduled to be launched | | | | |
| OMI | Ozone Monitoring Instrument | Daily<br>36 x 48 km | $O_3$, $SO_2$, $NO_2$ | EOS Aura (2003) |
| TES | Total Emission Spectrometer | Weekly<br>~100 km | $O_3$, $NO_x$, CO $H_2O$, $SO_2$, $HNO_3$ | EOS-Aura (2003) |
| CALIPSO | Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations | | Aerosol density and radiative properties | NASA CALIPSO (2004) |
| New instrument for tropospheric study to be proposed | | | | |
| GeoTRACE | Geostationary Observatory for Tropospheric Air Chemistry | Hourly<br>5x5 km | $O_3$, $NO_x$, CO, $SO_2$, HCHO | Future mission |

## Air Quality DSS: EPA CMAQ/Models-3




Models-3 Framework

- Multi-scale
  - Consistent model structures; supports *urban* through *regional* scales
- Multi-pollutant
  - $O_3$, PM, visibility, acid deposition, air toxics
  - Unified emissions control strategy analyses ("one atmosphere")
- Community Model
  - Stimulation of scientific and technological progress
  - Stimulation of model applications and evaluation
- Full Troposphere, includes clouds
- Modular Processes – Plug & Play

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**GeoTRACE** *is a mission concept to investigate the effects of urban and regional emissions, weather, and chemistry on the global pollutants: carbon monoxide, ozone, and aerosols.*


From the unique perspective of geostationary orbit, GeoTRACE provides measurements that

- ✓ are **time resolved** (hourly).
- ✓ measure key tropospheric **trace constituents** ($O_3$, CO, $NO_2$, $SO_2$, aerosol optical index, and others).
- ✓ have **excellent spatial** resolution (5 km x 5 km).
- ✓ occur **simultaneously** over continental or larger regions (domain is continental to full Earth disk).